NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

May 25, 2011

Cockpit Display Factual Report

Specialist's Factual Report
By Doug Brazy

1. EVENT SUMMARY

Location:	Brownsville, Tennessee
Date:	March 25, 2010
Time:	0600 Central Daylight Time (CDT)
Aircraft:	Eurocopter AS-350-B3
Registration:	N855HW
Operator:	Memphis Medical Center Air Ambulance Service d.b.a. Hospital Wing
NTSB Number:	ERA10MA188

On March 25, 2010, at 0600 central daylight time, a Eurocopter AS-350-B3, operated by Memphis Medical Center Air Ambulance Service, doing business as Hospital Wing, was destroyed when it impacted terrain while approaching Brownsville, Tennessee. The certificated commercial pilot and two flight nurses were fatally injured. Night instrument meteorological conditions were present in the area. The flight was operating on a company flight plan, and departed Jackson-Madison County General Hospital Heliport (TN05), Jackson, Tennessee, en route to Haywood County EMS Heliport (TN99), Brownsville, Tennessee. The positioning flight was conducted under the provisions of 14 Code of Federal Regulations Part 91.

An Avidyne Multifunction Display (MFD) was sent to the NTSB laboratory for examination.

2. GROUP

A group was not convened.

3. DETAILS OF INVESTIGATION

3.1. Items received

On March 30, 2010, the Safety Board's Vehicle Recorder Division received the following:

1. Manufacturer/Model: Avidyne FlightMax EX500 Multifunction Display
   Serial Number: 99169688

3.2. Device Description

The Avidyne FlightMax EX500 is a multifunction "moving map" display which can be configured to depict the aircraft's current position, flightplan, airports, navaids, terrain, other traffic, weather information, and other data. The pilot can select one of several "pages" to view, including several types of maps with or without weather information, navigational charts, trip data, and airport diagrams.

This unit was configured to receive satellite broadcast "XM WX Satellite Weather" information, which includes among other products, Next Generation Radar (NEXRAD) Doppler weather radar data.[1]

3.3. Description of Recording Contents

The EX500 does not record flight data or Global Positioning System (GPS) location information. It does however retain some information in nonvolatile memory for maintenance/diagnostics, as well as startup configuration purposes. The unit retains operating system log files (which indicate when the unit was powered on), and some of the user configurations (such as which features were selected for overlaying on the basemap). For each power cycle, the unit also logs a time-stamped list of weather products that were received during operation. The list includes the time, size and type of product received; the unit does not retain any of the content of weather products in nonvolatile memory.

[1] This report documents some of the weather products as provided by the XM WX Satellite Weather service. Detailed meteorological information relevant to this accident investigation can be found in the **Meteorological Factual Report** available in the public docket.

However, an archival copy of the weather data is maintained by the service provider. This archive uses a ground-based receiver to capture and store the live "data stream" as it is delivered, and it includes the contents of all the weather products.

The unit does not retain any data indicating which "page" or map was in use, or the range scale of the map.

The following data were recovered:

For the accident flight leg (from TN05 to accident site):

Operating system log file:

Indicated the MFD was powered up at 10:50:49 Coordinated Universal Time[2] (UTC), (05:50:49 Central Daylight Time (CDT))

Map configuration log file:

The configuration file indicates the following options were selected for the base map:

Map selected to "Heading up" mode (as opposed to "North Up")

Terrain depiction = off

Geodata = on (geodata includes political boundaries, water, and highways)

NEXRAD overlay = on, with "storm tops"

Lightning overlay = on

Traffic overlay = on

Metars overlay = on

Airmets overlay = on

Broadcast log file (XM weather messages received):

Table 1 below lists all of the weather messages received during the accident flight. More information about XM weather data can be found in Section 3.4 below.

[2] All of the data stored on the MFD are logged in the UTC timezone, and the MFD clock is synced to GPS time reference.

Table 1 - XM Weather Messages Received During Accident Flight

Time	Message	Action	Age	Size	Description	*[comment]*
10:52:34	1	Received	0	12125	Nexrad	*(Canadian Nexrad)*
10:52:48	9	Received	0	1889	Winds	*(U.S. winds aloft – winds at different altitudes are sent in multiple "Winds" messages, to cover winds aloft data at different levels up to 42000 feet)*
10:52:48	2	Received	0	208	SCITS	*(Storm cell identification and tracking)*
10:53:24	0	Received	0	18337	pid63	*(unknown)*
10:53:34	9	Received	0	1993	Winds	*(see above)*
10:54:08	42	Received	0	13814	TAFs	*(U.S Terminal Aerodrome Forecasts)*
10:54:08	2	Received	0	189	SCITS	*(See above)*
10:54:18	9	Received	0	2073	Winds	*(See above)*
10:54:20	0	Received	0	773	sigmet	*(U.S. Significant Meteorological Information – only convective sigmets are displayed on MFD)*
10:54:24	70	Received	0	474	PIREP	*(Pilot Reports)*
10:55:04	9	Received	0	2103	Winds	*(see above)*
10:55:16	6	Received	0	371	Strikes	*(lightning strike locations)*
10:55:16	2	Received	0	168	SCITS	*(See above)*
10:56:00	1	Received	0	36117	Nexrad	*(U.S. Nexrad – The MFD will not display the Nexrad data until the "Nexrad", "Nexrad Coverage", and "Precipitation Type" messages have all been received)*
10:56:00	4	Received	0	31	Nexrad coverage	*(see Nexrad - above)*
10:56:00	42	Received	0	3378	TAFs	*(see above)*
10:56:20	8	Received	0	5954	Precipitation type	*(see Nexrad - above)*
10:56:20	9	Received	0	2280	Winds	*(see above)*
10:56:32	73	Received	0	5899	Canada winds	*(Canadian Winds aloft)*
10:56:36	51	Received	0	58	P.R. Radar	*(Puerto Rico Nexrad)*

Time	Message	Action	Age	Size	Description	*[comment]*
10:56:36	2	Received	0	168	SCITS	*(see above)*
10:56:38	9	Received	0	2076	Winds	*(see above)*
10:57:20	9	Received	0	2138	Winds	*(see above)*
10:57:56	2	Received	0	159	SCITS	*(see above)*
10:58:12	9	Received	0	2153	Winds	*(see above)*
10:58:20	74	Received	0	235	Canada SIGMET	*(Canadian Significant Meteorological Information)*
10:58:24	77	Received	0	72	Canada Convective outlook	*(Canadian convective weather outlook)*
10:58:24	75	Received	0	1417	Canada Warnings	*(Canadian weather warnings)*
10:58:48	9	Received	0	1867	Winds	*(see above)*
10:59:02	2	Received	0	180	SCITS	*(see above)*
10:59:34	34	Received	0	3687	ZISO	*(see above)*
11:00:16	2	Received	0	212	SCITS	*(see above)*
11:00:22	9	Received	0	2058	Winds	*(see above)*
11:00:24	6	Received	0	377	Strikes	*(see above)*

3.4. About XM WX Satellite Weather

XM WX Satellite Weather is a weather data service available from Sirius XM Satellite Radio. Weather data are available via a subscription service and include "products" such as:

- High-Resolution NEXRAD[3] Radar
- Lightning
- Satellite Imagery
- METARs
- Winds Aloft
- Freezing Level

A 3rd party service provider collects all the weather data from several different sources, processes it, packages it and delivers it to Sirius XM Radio for distribution to the subscribers. The weather data is transmitted to the subscribers via satellite to appropriately equipped receiver/display equipment on board the aircraft. The Pilot's Guide for the MFD offers the following advisory information with regard to the weather information (referred to as "Datalink weather"):

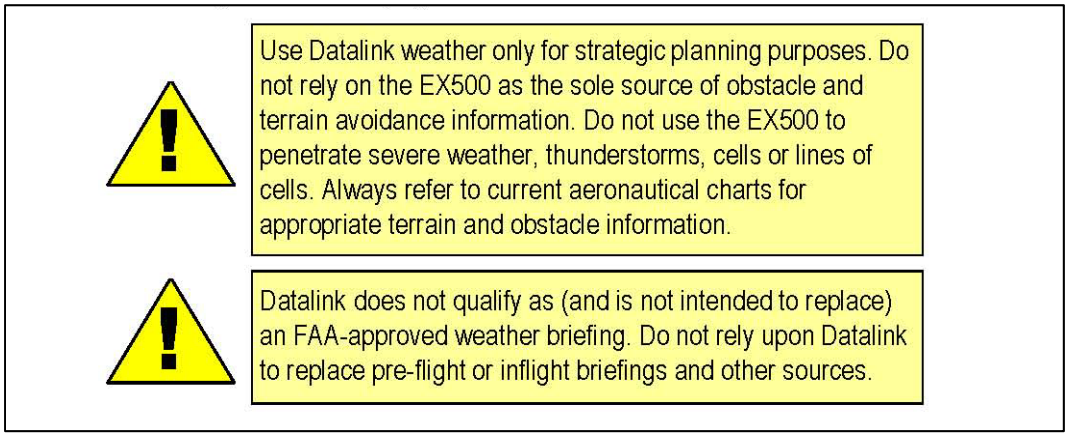

Figure 1 - Weather Advisory Information

3.4.1. Description of NEXRAD Radar Data

The service provider collects the NEXRAD radar data from multiple radar antennas, and compiles it into a single "mosaic" dataset which covers the entire continental U.S. This mosaic (and its time of creation) is sent to the subscribers at approximately 5 minute intervals.

The NEXRAD data is provided to the on-board display equipment as a listing of coordinates, intensity, and precipitation type, at roughly 2x2 kilometer lateral resolution.

[3] NEXRAD is an acronym for Next Generation Radar, and generally refers to data gathered by a system of WSR-88D Doppler weather radar antennas operated by the National Weather Service. The XM WX Satellite Weather service gathers radar data from this system as well as other sources.

Eight discrete levels of intensity are available (including one for “no data”). The display unit design determines how to present that data on the display, including which colors to use to represent intensity and precipitation type at the surface (rain, snow or mixed). An example of NEXRAD data displayed on an EX500 is shown in Figure 2. The color scale used by the EX500 is shown in Figure 3.

Figure 2 - Example MFD Map with NEXRAD Weather Data

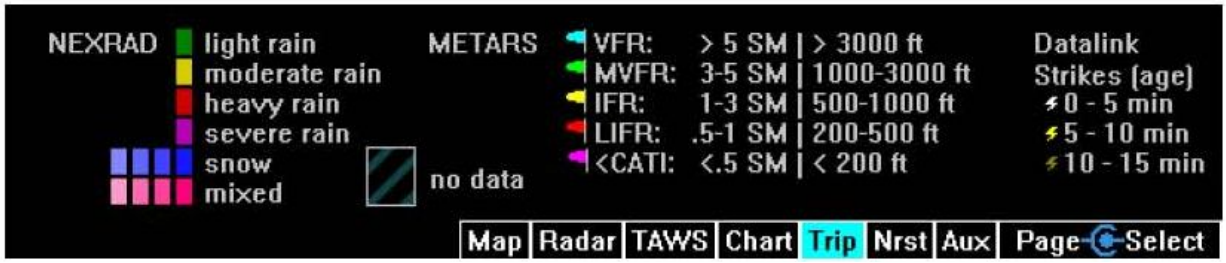

Figure 3 - Color Scale

NEXRAD Data Latency

The NEXRAD weather product delivered by the service provider is not a “real time” indication of current conditions. There is some latency involved in the collection, processing and delivery of the NEXRAD radar data to the EX500 MFD. The Pilot’s Guide for the EX500 provides the following advisory information about NEXRAD data:

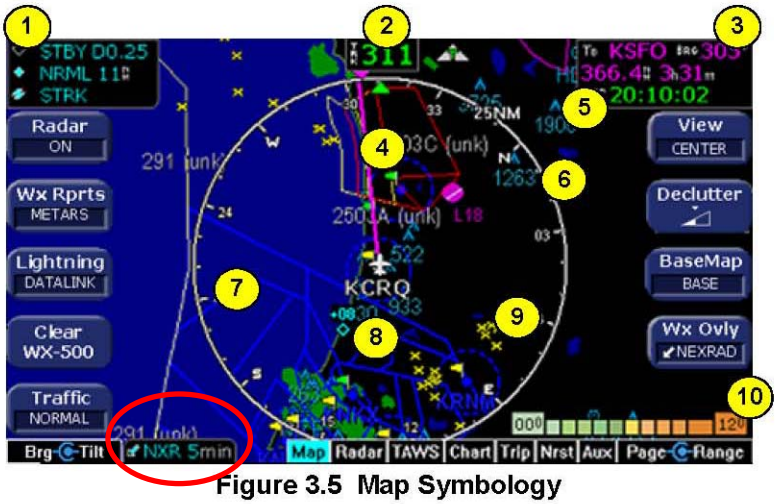

Figure 3.5 Map Symbology

1) **Sensor Status Box**—Displays the status of the available sensors including radar, traffic, lightning and both Narrowcast and Broadcast Datalink. The NEXRAD (NXR) display includes the age of the NEXRAD data. If more than three sensors are present, NEXRAD status displays in the alternate status box location (**1a**).

When using Datalink weather, monitor the data age so you are aware of the time elapsed since the last weather update.

Figure 4 - NEXRAD Advisory Information

The EX500 MFD provides an indication of the age of currently displayed NEXRAD data. The tab in the lower left corner of Figure 4 which reads “NXR 5min” indicates that the NEXRAD data is 5 minutes old. However, this is actually the age of the radar data “mosaic” product (described below) produced by the service provider, and not the time elapsed since the actual weather conditions. There are several categories of data latency, defined and described below, which affect the “overall latency” of NEXRAD weather information in this particular case. For the purposes of this report “overall latency” refers to the estimated time lapse from when the precipitation conditions were detected by radar, until the data are available for display on the EX500 MFD.

Data Acquisition Latency

Data Acquisition Latency, used here, refers to the latency associated with the radar antenna operation and the "raw" products available from it. The radar antennas are operated one of several modes called Volume Coverage Patterns (VCPs)[4], which take from approximately 4 minutes to 10 minutes to complete depending on the particular mode of operation, before the VCP repeats. Base Reflectivity data[5] are available from single elevation scans or as composited data from multiple elevation scans, taken over the course of the VCP. The XM WX Satellite Weather service provider typically uses 4 individual elevation scans from one or more VCPs to create their own composite data set for a given antenna, to be included in the mosaic.

By requirement, the National Weather Service (NWS) must make the data from any individual scan available within 60 seconds after the scan is complete. However the data are typically available within 10 – 20 seconds or less. By convention, the NWS time stamps each individual scan (and all of the products associated with any given VCP) with the time that the VCP *began*. This is the start time of the first elevation scan in the VCP. The NWS uses a GPS based timesource to time stamp the products, and uses the UTC timezone. The start time of individual scans as noted in this report were calculated using the published time of the start of the VCP, and the table of scan durations ("Periods") in Attachment I.

Mosaic Creation Latency

NEXRAD data are provided by the XM WX Satellite Weather in a "mosaic" type of format. The mosaic is a single dataset for the entire coverage area (for example, the United States) which is created by combining data from hundreds of radar antennas located throughout the coverage area. Each radar antenna operates independently of the others, and the "update rate" and information available from each radar antenna varies, depending on the mode the radar is operating in. As a result, each mosaic dataset contains data from many different sources, and from different times, so the latency varies by location. In addition, data in the mosaic from any single antenna may reflect a composite of several elevation scans, taken at different times.

According to the service provider, a mosaic is created approximately every 5 minutes, using the latest available NEXRAD data at the time the mosaic is created. Any NEXRAD data that is older than 15 minutes will be excluded from the mosaic, and the coverage area for the exclusion is annotated. The "timestamp" included with each mosaic indicates the time that mosaic was created. As a result, an age indication of "NXR 5min" on the EXC500 MFD means that any given data in the mosaic are at least 5 minutes old, but could be up to 20 minutes old.

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[4] WSR-88D radars are typically operated in one of several (VCPs) which are comprised of a number of "elevation scans" (one revolution of the antenna) at varying operational parameters and elevation angles, before the VCP is repeated. Individual elevation scan durations vary from 12 - 90 seconds, complete VCPs vary from about 4 - 10 minutes. At the time of the accident, the WSR-88D radar located at KQNA was operating in VCP 212 mode, which includes 17 elevation scans, and takes about 4.3 minutes to complete the entire VCP.

[5] Base Reflectivity data is used to generate the mosaic provided by XM WX Satellite Weather.

Transmission Latency

The typical transmission latency for NEXRAD data (the time from when the mosaic is created until it arrives at the receiver in the aircraft) is about 60 seconds. Because the age indicator measures the elapsed time since the mosaic was created, any delays due to processing or transmission after the mosaic is created will be reflected in the age indication.

Display Latency

In order to display the most recent NEXRAD data, the EX500 MFD requires that 3 separate messages be received from the XM WX Satellite Weather Service (the "Nexrad", "Nexrad Coverage", and "Precipitation Type" messages). On the day of the accident, the "Nexrad" and "Nexrad Coverage" messages were typically received at the same time (to the nearest second), and the "Precipitation Type" message typically followed 10 to 38 seconds later. This latency is also reflected in the age indication on the MFD display.

Overall Latency on the Accident Day/Location

By comparing the NEXRAD data archived from the XM WX Satellite Weather provider, to the data obtained from the National Weather Service[6], an estimate of the overall latency on the day of (and at the location of) the accident was calculated.

The figures below depict excerpts of archived NEXRAD data on the day of the accident. In these Figures, the blue helicopter icon depicts the departure location for the accident flight (Jackson-Madison County General Hospital Heliport - TN05), the red helicopter icon depicts the destination location (Haywood County EMS Heliport - TN99), and the red "+" symbol represents the accident site.

Figure 5 and Figure 8 are representations of the data provided by the XM WX Satellite Weather service. The actual format of the transmitted data is numeric values for coordinates and intensity levels. Imagery is not transmitted. The design of the display unit (EX500 MFD in this case) or presentation software determines which colors are used to represent the numerical values. These images utilize a color scale that is different from that used by the EX500 MFD. These images depict 7 discrete levels of Base Reflectivity (at most). The EX500 MFD uses 4 colors (shown in Figure 3) to represent ranges of these 7 reflectivity levels.

Figure 6, Figure 7 and Figure 9 are representations of the "Level III" radar data as archived by the NWS, which is the source data that is used by the XM WX Satellite Weather service provider to create the "NEXRAD products" it delivers. This data is also sourced (and archived) in a numerical format. These images utilize a different color scale than the images in Figure 5 and Figure 8, and represent 15 discrete levels of Base Reflectivity.

[6] NEXRAD Level III Base Reflectivity data from the WSR-88D antenna at KQNA.

Figure 5 is a representation of the NEXRAD mosaic data provided by the XM WX Satellite Weather Service[7]. This mosaic creation time was 05:55:00 CDT, and this data was available for display on the EX500 MFD aboard the accident helicopter at 05:56:20 CDT[8], which was about 4 minutes prior to the accident. This was the first and only NEXRAD data received during the accident flight. Prior to this time, there would not have been any NEXRAD data displayed during the accident flight. At this time, the NEXRAD age indicator should have indicated the NEXRAD mosaic product was 1 minute old. For reference, the magenta line from the destination airport to the leading edge of the yellow region is about 7 nautical miles long.

Figure 5 XM Mosiac data at time stamped at 5:55:00 am CDT

A review of the archived data from the National Weather Service indicated that at about the time this NEXRAD update was received by the EX500, the actual conditions were as depicted in Figure 6 (approximately). Note that the color scale used in Figure 6 is not the same as in Figure 5.

[7] This radar image was provided by the service provider, and **does not depict the color scale used by the Avidyne EX500 MFD.** This image does not include the storm top data, which was selected for display on the MFD.

[8] This NEXRAD data mosaic was received at 05:56:00 CDT, however it was available for display after the "precipitation type" message was received at 05:56:20 CDT.

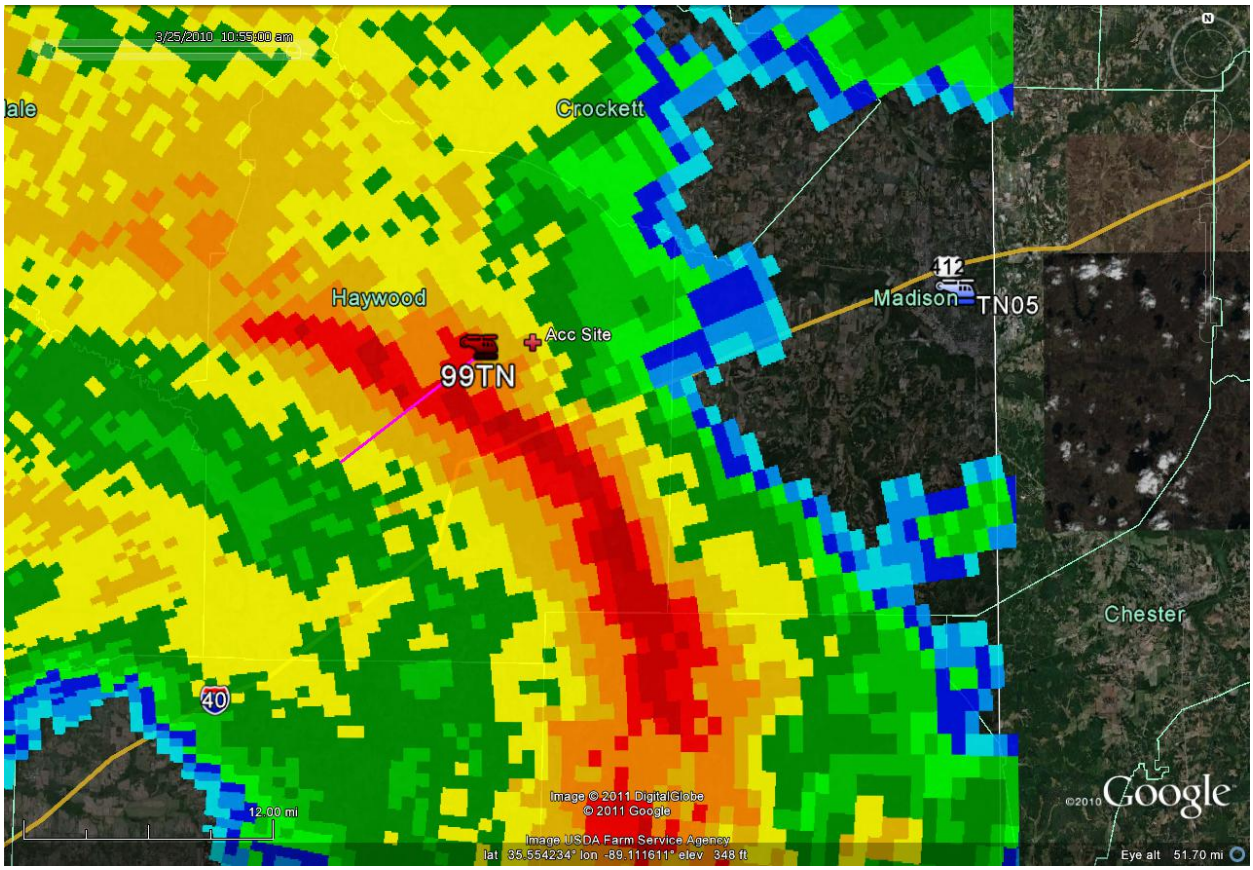

Figure 6 - NWS Data from scan beginning at 05:56:35 CDT

Figure 6 the depicts data from the VCP which began at 05:55:19 CDT. This image specifically shows the data from the individual 1.3 degree elevation scan, which began at about 05:56:35 CDT.

Further review of the archived radar data from the National Weather Service indicates that the data used to create the mosaic in Figure 5 was most likely collected by the radar antenna located at KQNA during the VCP which began at 05:50:43 CDT. During that VCP, the individual elevation scan (1.3 degrees) most similar to the data in the mosaic, began at approximately 05:50:59.

The overall latency in this case was approximately 05:21 (min:sec)[9]. Figure 7 below shows the NWS scan from 05:50:59.

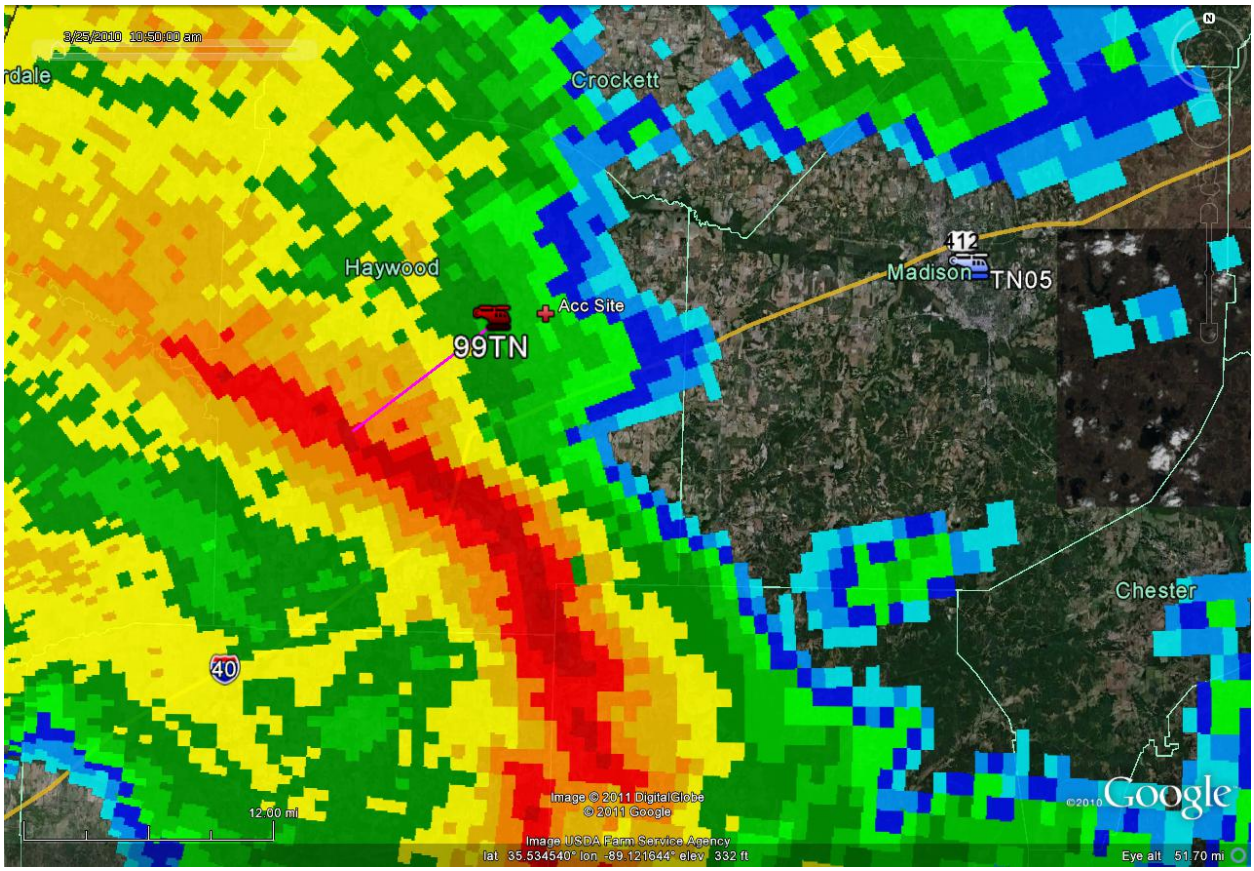

Figure 7 - NWS Data from scan beginning at 05:50:59 CDT

[9] Or slightly less than this value, as the radar timing information is based on the start of the elevation scan.

Previous NEXRAD update

During the accident flight, the EX500 MFD received only one NEXRAD update as noted above. From the time the unit was powered on until it received that update, no NEXRAD data could have been presented on the unit. However, during the previous flight inbound to the Jackson-Madison County General Hospital Heliport (TN05), the unit received the NEXRAD data 3 times. Of these, the last one was received at 05:31:00 CDT (about 5 minutes prior to shutoff) and was ready to be displayed at 5:31:28. At this time, the NEXRAD age indicator should have indicated the NEXRAD mosaic product was 1 minute old.

Figure 8 below is a representation of the NEXRAD mosaic data provided by the XM WX Satellite Weather Service, timestamped at 05:30:00 CDT.[10] (note the scale of this image is larger than the image in Figure 5).

Figure 8 - XM Mosiac data time stamped at 5:30:00 am CDT

[10] The radar image was provided by the service provider, and **does not depict the color scale used by the Avidyne EX500 MFD.** This image does not include the storm top data, which was selected for display on the MFD.

Review of the archived radar data from the National Weather Service indicates that the data used to create the mosaic in Figure 8 was most likely collected by the radar antenna located at KQNA during the VCP which began at 05:23:09 CDT. During that VCP, the individual elevation scan most similar to the data in the mosaic (0.5 degree), began at approximately 05:23:09 CDT

The overall latency in this case was approximately 08:19 (min:sec)[11]. Figure 9 below shows the NWS scan from 05:23:09.

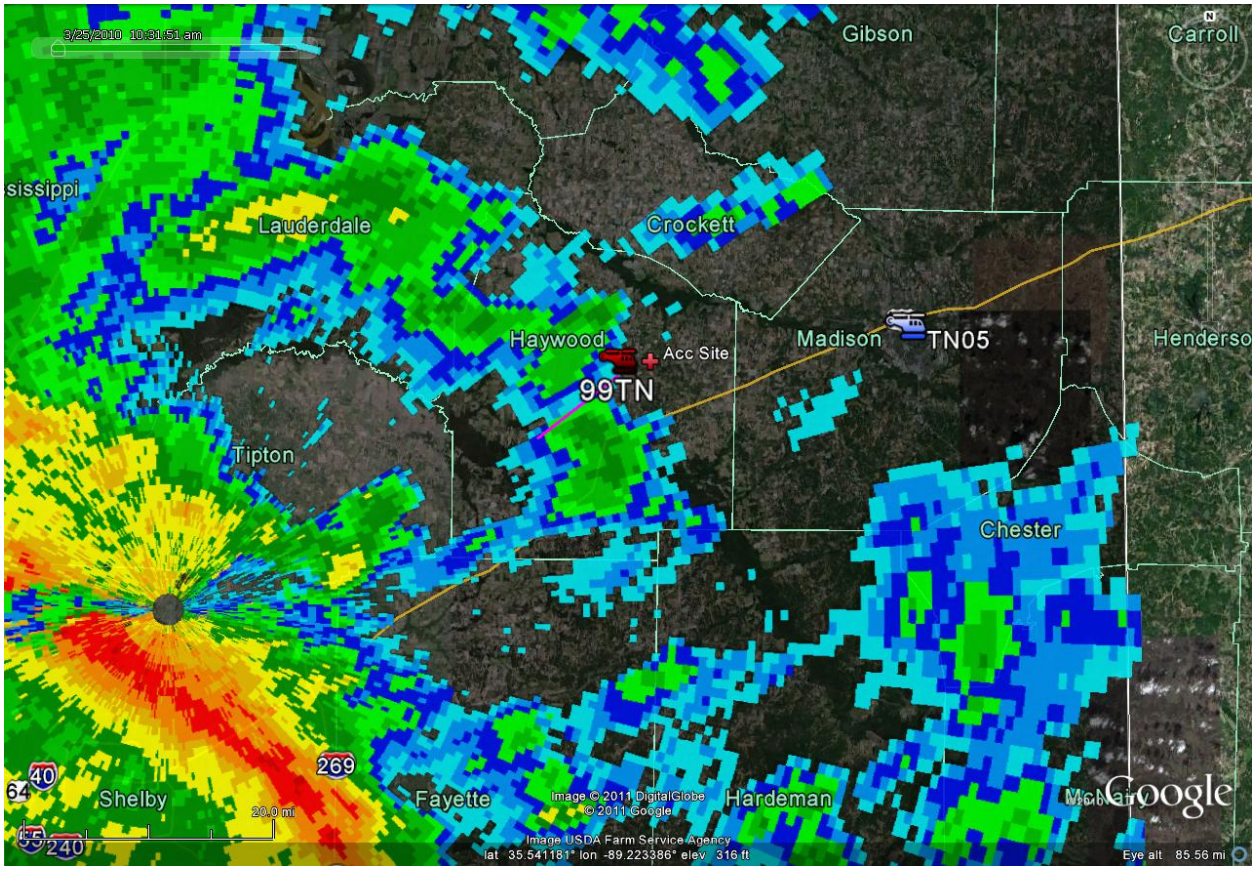

Figure 9 - NWS Data from scan beginning at 05:23:09 CDT

Time of Accident

The broadcast log files containing the time stamped list of XM WX Satellite Weather products received, was used to determine the accident time, based on a GPS referenced clock.

The last record stored in the log for the accident flight was:
"11:00:24,6,Received,0,377,Strikes" (time in UTC)

[11] Or slightly less than this value, as the radar timing information is based on the start of the elevation scan.

According to the weather data service provider, the next message received by the ground station (which is used to archive the weather data stream) occurred at 11:00:40 UTC (time also referenced to a GPS clock). The EX500 MFD did not receive this message.

The accident time was therefore between 06:00:24 and 06:00:40, CDT, based on a GPS referenced clock.

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Attachment I
Table of Scan Periods for Volume Coverage Pattern 212
For the WSR-88D Weather Radar

Table 13: VCP 212 Characteristics

Close Window

Scan				Surveillance		Doppler PRF No.				
Angle (°)	AZ Rate (°/sec)	Period (sec)	WF Type	PRF No.	# Pulses	4 #Pulse	5 #Pulse	6 #Pulse	7 #Pulse	8 #Pulse
0.5	21.15	17.02	SZCS	1	15	--	--	--	--	--
0.5	16.90	21.30	SZCD	--	--	--	--	64	--	--
0.9	21.15	17.02	SZCS	1	15	--	--	--	--	--
0.9	16.90	21.30	SZCD	--	--	--	--	64	--	--
1.3	21.15	17.02	SZCS	1	15	--	--	--	--	--
1.3	16.90	21.30	SZCD	--	--	--	--	64	--	--
1.8	24.64	14.61	B	1	3	25	29	32	34	37
2.4	26.40	13.64	B	2	3	25	30	32	35	38
3.1	26.40	13.64	B	2	3	25	30	32	35	38
4.0	26.40	13.64	B	2	3	25	30	32	35	38
5.1	28.01	12.86	B	3	3	25	30	32	35	38
6.4	28.01	12.86	B	3	3	25	30	35	38	40
8.0	28.40	12.68	CDX	--	--	30	35	38	41	44
10.0	28.88	12.46	CDX	--	--	29	34	37	40	44
12.5	28.74	12.53	CDX	--	--	29	34	37	40	44
15.6	28.74	12.53	CDX	--	--	29	34	37	40	44
19.5	28.74	12.53	CDX	--	--	29	34	37	40	44

Notes:

- ***Default*** Doppler PRFs are underlined; Doppler PRFs are editable for all batch cuts, while SZ-2 cuts are ***not*** editable
- Sum of periods, which is "data collection" time = 259.12 secs / 4.31 mins. Transition times will vary.
- Volume scan update time is about 4.5 minutes

Close Window